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Microfluidic device for the rapid coating of magnetic cells with polyelectrolytes

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ABSTRACT

We demonstrate a rapid method of coating a layer of polymer onto magnetically modified yeast cells, so-called "cyborg cells", in continuous flow within a microfluidic chamber. Laminar flow streams of polyelectrolyte and washing buffers were generated across the chamber, and the magnetic cells were deflected sequentially through the co-flowing streams via an external magnet, allowing polyelectrolyte deposition onto the cells immediately followed by the washing step, all in less than 90 s. This simple deposition technique shows promise for the functionalization of such cyborg cells for applications including bioelectronics, bioanalysis, and toxicity screening, while the addition of more reagent streams would enable the fabrication of multilayered capsules.

1. Introduction

The functionalization of living cells with polymers or nanoparticles to yield so-called "cyborg cells" is an emerging field that shows great promise for a number of applications [1], including their incorporation into novel biosensors [2], toxicity screening devices [3], bioelectronics [4], and bioanalytical chemistry [5]. The fabrication of cyborg cells is most commonly achieved via the layer-by-layer (LbL) technique [6,7], in which alternating layers of oppositely charged polyelectrolytes are coated onto the cell template. However, this procedure consists of many deposition and washing steps, yielding a laborious and time-consuming process with incubation times of 10–20 min per layer and up to three additional washing steps.

Microfluidic devices present an attractive alternative for achieving fast and automated deposition of materials onto core templates. Such platforms consist of networks of channels that feature dimensions in the range of micrometers, and offer advantages of reduced reagent volumes and waste production, short diffusion distances, and laminar flow regimes that allow greater control over fluidic processes. So far, on-chip LbL methods have utilised droplet-based systems [8–12]. The coating of microparticles with an aqueous layer in an oil phase has also been demonstrated [13]. However, so far there have been no examples of employing microfluidic techniques for the preparation of cyborg cells, which continue to be fabricated via time-consuming conventional methodologies. Furthermore, the ability to manipulate such cells via magnetic fields within microchannels has not previously been explored, in particular their on-chip deflection in continuous flow.

In this communication we propose an elegant microfluidic method for the one-step labeling of cyborg cells with polyelectrolytes in continuous flow, via the application of magnetic forces [14]. The platform consists of a microfluidic chamber across which co-laminar streams of polyelectrolyte and washing buffers are generated in the x-direction (Fig. 1a). Living cells functionalized with magnetic nanoparticles [15] (Fig. 1(b) and (c)) are introduced into the chamber and deflected through the polyelectrolyte and washing stream(s) in the y-direction via a magnetic field, allowing the reagent to react or bind to the surface of the passing magnetic cells. This simple setup allows the reaction and washing processes to be condensed into a single step, thereby reducing procedural times and reagent consumption, as has previously been applied to bioassays [16–18]. The deposition of a polyelectrolyte layer onto magnetic cells offers the potential for genotoxicity and cytotoxicity biosensor applications, whilst the addition of multiple layers followed by dissolution of the cells could yield hollow capsules that may be employed as drug delivery vehicles [19–21].

2. Experimental procedures

The microfluidic chip design featured an 8 mm long by 3 mm wide deposition chamber with 5 inlet channels and 5 outlet channels (Fig. 2a), and was fabricated in glass to a depth of 20 μm using conventional photolithography and wet etching methods [22] (Fig. 2b). Microchannels were either used untreated,

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